An Evaluation of Economic Loss Caused by Health Effects of Ambient Air Pollution and Development of a Circular Economy Model to Combat over Indo-Gangetic Basin of India

Synopsis

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1. Introduction

Air pollution has become a global problem as a result of urbanization and significant energy use. The increase in population, unplanned economic expansion, increasing industrial output, and unprecedented growth in the use of passenger vehicles have increased CO_2 and other pollutant emissions, such as particulate matter and have caused air pollution, global warming and climate change. Air pollution, global warming and climate change are hurting agriculture, materials, human health, and the entire ecosystem. The health effect of air pollution has become terrible and affects general welfare of the population. The health effects have important economic ramifications. Hence, combating the threat of air pollution, particularly its health and economic effects is essentially required and needs a long-term and holistic approach. Sustainable production and consumption-based development of society can be an effective strategy for decreasing pollution and economic loss which can be achieved by circular economy.

1.1 Air Pollution and economic consequences

Air pollution has become a big problem not on a global scale, but also at a regional and local level. The principal pollutants that produce air pollution include particulate matter, ammonia, carbon monoxide, sulphur dioxide, nitrous oxides, methane, carbon dioxide, and chlorofluorocarbons. Air pollution in our environment can be caused by both human activity and natural sources. The health of humans and other living organisms is harmed by air pollution. According to the World Health Organization (WHO), air pollution kills seven million people globally each year and9 out of 10 people breathe air that contains high levels of contaminants and surpasses WHO guideline limits. Particulate matter concentrations are substantially greater than WHO guidelines in numerous parts of the world. Air pollution is a huge problem that has both direct and indirect consequences on people and the economy. The long-term health consequences of air pollution include heart disease, lung cancer, child health concerns, respiratory disorders such as emphysema, and damage to people's nerves, brain, kidneys, liver, and other organs. Exposure to particulate matter and additional contaminants in the atmosphere cause a variety of diseases and allergies are respiratory diseases (including asthma and changes in lung function), cardiovascular diseases, adverse pregnancy outcomes (such as preterm birth), and even death.

Air pollution is one of the most important worldwide issues, with economic implications. It lowers labour productivity, raises healthcare costs, and lowers food yields. All of them harm a country's gross domestic product (GDP). Particulate pollution costs human lives and impairs people's abilities in a variety of ways, including greater rates of asthma, diabetes, and chronic respiratory disorders, all these lead to reduced labour force participation rates.

According to an OECD (Organization of Economic Co-operation and Development), report published in 2016, global air pollution-related healthcare costs are expected to rise from US$ 21 billion in 2015 to US$ 176 billion in 2060, with the economic consequences of outdoor air pollution stating that projected increases in $PM_{2.5}$ and ozone concentrations will have significant economic consequences. Annual lost working days, which have an impact on labour productivity, are expected to reach 3.7 billion by 2060 on a global scale. The economic consequences of outdoor air pollution are expected to progressively rise from 0.3 % in 2015 to 1.0 % in 2060, according to projections.

Air pollution (including indoor and outdoor) caused 5.5 million premature deaths worldwide in 2013 (OECD 2016). By 2060, outdoor air pollution might cause 6 to 9 million premature deaths per year, costing 1% of world GDP, or USD 2.6 trillion each year. The annual global welfare expenditures of premature mortality due to outdoor air pollution are expected to climb from US$ 3 trillion in 2015 to US$ 1825 trillion by 2060. Furthermore, worldwide welfare expenditures linked with pain and suffering from sickness are expected to reach $2.2 trillion by 2060, up from $300 billion in 2015 (OECD, 2016).

1.2 Circular Economy

The circular economy (CE) was first proposed in 1988 as a strategy to shift away from a take-make-dispose mentality and toward a circular, restorative, and regenerative model and society. CE is built on the simple concepts of waste reduction, material reuse, and product and service development. It allows rethinking how we might produce value in our economies while reducing the liabilities that come with being green and inclusive. The circular economy identifies ways to improve the economy while decreasing climate change and pollution. Our globe is just 9.1% circular, according to the first Circularity Gap Report, published in January 2018. The Circularity Gap Report (2020) stated that the global economy is just 8.6% circular. According to the Circularity Gap Report (2021), circular

strategies could reduce global GHG emissions by 39 % and non-circular resource use by 28 %. If control measures are not taken and business continues as usual 65 billion tonnes of GHG emissions will be released in 2030.

A circular economy, which is founded on the principles of reducing, reusing, and recycling materials and things, can be a significant instrument in combating the threat of air pollution. Air pollution can be reduced by promoting sustainable and circular development in the country. Circular development is a model of economic, social, and environmental protection. Circular economy's three primary elements aid in the reduction of waste and pollution, the reuse of products and resources, and the recycling and regeneration of natural systems. It serves as a vehicle for achieving several United Nations Sustainable Development Goals (SDGs).

A circular economy, in reality, contributes to at least 12 of the 17 SDG goals. It provides an opportunity to address difficult-to-reduce emissions and hasten the transition to a carbon-free economy. It equips us with the tools required to combat climate change and biodiversity loss while also meeting critical social needs. It has the ability to increase prosperity, jobs, and resilience while reducing greenhouse gas emissions, waste, and pollution (Ellen MacArthur Foundation, 2021).

Circular economy approaches that limit resource consumption can aid in the reduction of global greenhouse gas emissions and the mitigation of climate change's detrimental consequences and health related economy loss. In a circular economy, products and materials circulate through supply chains as long as feasible in a high-value state of usage.

The circular economy also investigates how reducing climate change and pollution might help our economy. Natural resources are limited on this planet. The linear economy is not only reliant on limited resources but also produces non-biodegradable trash. These issues, however, have an opportunity and a remedy. The product life cycle does not terminate if firms reuse waste generated during production and individuals reuse the products. Only a properly functioning circular economy with environmental, social, and economic benefits can make the country clean.

The circular economy strives to keep products, components, and resources useful while also retaining their value (Ellen MacArthur Foundation, 2015 and 2016).It encourages waste reduction and growth while conserving the environment and natural resources. By 2030, it is estimated that half a trillion

dollars of India's GDP can be preserved through circular economy business models (FICCI, Circular Economy Symposium, 2018). Circular economy is an option that has the potential to provide up to US$ 4.5 trillion in global economic benefits by 2030 (Accenture and World Economic Forum, 2021). In 2019, more than 92 billion tonnes of materials were extracted and processed, accounting for almost half of all CO_2 emissions globally. Circular economy has the potential to reduce vehicle lifetime emissions by up to 75% and non-circular resource consumption up to 80% by 2030 (Accenture and the World Economic Forum, 2021).

1.3 Problem in the Indian Context

Air pollution is of a global health concern, and the economic costs associated with it are enormous. Air pollution causes a huge number of deaths in heavily populated areas such as India and China (OECD, 2016). India is wrecked by chronic air pollution, and the scale of the problem is unfathomable. India has 22 of the world's 30 most polluted cities and ranks third in terms of total emissions (World Air Quality Report, 2020). One of the primary contributors to India's leading $PM_{2.5}$ emission sources is the transportation industry. Industrial pollution accounts for 51% of pollution in India, whereas automobiles account for 27%, crop burning accounts for 17%, and fireworks account for 5%.Because of the high population density and a large number of early deaths in India, air pollution is the leading cause of death. In 2019, India's economic loss owing to lost output due to early mortality and illness due to air pollution was 1.4 % of GDP, or US$ 36.8 billion (INR 2.6 lakh crore). The cost of air pollution as a proportion of state GDP was higher in northern and central India, with the biggest losses in Uttar Pradesh (2.2 % of GDP) and Bihar (2 % of GDP) (Indian Express, 24 Dec 2019). The circular economy has the potential to reduce pollution and CO_2 emissions by 39% in particular (Taylor, 2021). According to the Ellen MacArthur Foundation's research (2021), India's yearly material consumption will double to 14.2 billion tonnes by 2030 due to population increase. Though, Indian government has been developing regulations and encouraging programmes to move the country toward a circular economy, there is a need to rely more on a circular economy approach that prioritizes people, the environment, and net economic gains. By adopting circular economy concepts, India can reap yearly benefits of around US$ 624 billion in 2050, which is equivalent to 30% of India's present GDP. In 2050, it would also result in a 44 % reduction in greenhouse gas

emissions, resulting in an improved quality of life for the city's population (Ellen MacArthur Foundation, 2016). Hence, assessment of health risk and evaluation of economic loss due to air pollution is very important and development of circular economy model is need of the time to combat the menace of air pollution.

2. Literature Review

The circular economy has the potential to significantly reduce the negative consequences of air pollution on the economy. Several studies on various aspects of the problem and causes of air pollution, as well as its consequences on health and the economy undertaken in India and overseas have been reviewed. A summary of these studies, both worldwide and in Indian context, is offered below.

2.1 International status

Several researchers described numerous emission sources and monitoring methods. They believe that motor vehicles and industrial processes are important contributors to air pollution (Adhikary et al., 2020; Adeyanju and Manohar, 2017; Ghorani-Azam et al., 2016; Tanimowo, 2016). According to Adhikary et al. (2020), a continuous monitoring system is one of the greatest solutions to reduce vehicle pollution since it allows for constant emission monitoring via the Internet of Things (IoT). Adeyanju and Manohar (2017) studied the effects of CO, NO_2, SO_2, CO_2, and HC on ambient air quality in selected Lagos metropolis areas (Oshodi, Ojota, Yaba, and Lekki). Ghorani-Azam et al. (2016) stated that a robust environmental protection body should lead the cooperation between several departments involved in air pollution. According to Tanimowo (2016), more than half (59.33 %) of automobiles on city highways generate visible smoke. He emphasized the necessity for more severe transportation policies concerning urban environmental planning and management.

Several scholars used various approaches to examine the costs of population health owing to air pollution (Sharma, 2018; Maji et al., 2018; Brauer et al., 2007; Sommer et al., 1999). Sharma (2018) used an unbalanced panel analysis of 17 advanced economies from 1870 to 2013 to look at the health-growth link. The study discovered that population health proxies based on life expectancy have a considerable beneficial effect on both real incomes per capita and growth using the Barro-type growth regression model and panel generalized method of moments (GMM) and mentioned that per capita

income can be boosted through focused policy attention on population health. Maji, et al.(2018) reported that the external costs of $PM_{2.5}$ pollution associated mortality and morbidity have been estimated to be 101.39 billion US$, which is 0.91% of the total GDP in China. In the subgroup with IgE (immunoglobulin E) measurements, Brauer et al. (2007) discovered positive associations between traffic-related pollution and specific sensitization to a common food allergen, but not total IgE and also discovered positive associations between traffic-related pollution and respiratory infections, as well as some asthma and allergy measures. Sommer et al. (1999) used the willingness-to-pay in each country (Austria, France, and Switzerland) to estimate the health costs of road traffic, with mortality costs accounting for more than 70% of the total.

Air pollution can be lowered by adopting green technology and electric vehicles' role in lowering air pollution has been studied (Ahuja et al., 2020; Raut, 2003) in various places. To enable a circular economy, Ahuja et al. (2020) proposed new electric car ownership structures as a viable option. Vehicles are responsible for around 67 % of the total particulate matter load in Kathmandu, and particulate matter is the valley's largest source of air pollution (Raut, 2003).

Some research (Liu et al., 2017; Howell et al., 2003) has focused on people's perceptions of air pollution danger. Liu et al. (2017) demonstrated that Wuhan residents are concerned about air pollution and agree that improving air quality (AQ) is everyone's responsibility; they asked for specific efforts to enhance AQ and underlined the need for greater education and more environmental awareness initiatives. Chronic sickness status and age were connected with perceptions of disease caused by air pollution (Howel et al., 2003), while gender and material deprivation were not central to differences in risk perceptions among the population.

A circular economy helps to minimize carbon dioxide emissions and so encourages economic development (Ferrante and Germani, 2020; Liu et al., 2018; Donald et al., 2015; Su et al., 2013). Ferrante and Germani (2020) found that the lagged level of employment in the circular economy industry is negatively correlated with unemployment and a decrease in the number of people at risk of poverty or social exclusion, and stated that the circular economy is important for economic growth. The Chinese plastic recycling industries' (CPRI) contribution to CO_2 emission reduction increased from 7.67 million tonnes (MT) in 2007 to 14.57 MT in 2016 (Liu et al., 2018). The marginal product

of recyclable inputs, the recycling ratio, the cost of utilizing environmentally damaging inputs, and the amount of pollution resulting from the use of polluting inputs are all factors that influence economic growth (Donald et al., 2015). The Circular Economy offers a way to aid economic development, reduce carbon dioxide emissions, and improve policy recommendations for the future, as well as a way for businesses and industries to improve their competitiveness and remove green barriers in international trade (Su et al., 2013).

2.2 National Status

According to several studies, the automotive sector is the leading source of air pollution (Yadav and Sahay, 2017; Balasundaram et al., 2017; Shrivastavaet al., 2013; Mahadevappa, 2012; Singh et al., 2001). By using a linear correlation technique, Yadav and Sahay (2017) discovered a very high degree of positive association between automobile sales and CO_2 emissions, indicating that the turnover of motorized vehicles accounts for roughly 8% of India's GDP. According to Balasundaram et al. (2017), the Internet of Things can improve the detection level and accuracy of the exhaust monitoring system by allowing it to run continuously, be economical, and be controlled tractably IoT. Shrivastava et al. (2013) reported that transportation contributes a significant amount to environmental pollution, with CO_2 being the most significant pollutant, accounting for 90% of total emissions. Mahadevappa (2012) reported that transportation activities have caused about 70% of the ambient air quality degradation in Bangalore in the last few years, and recommended vehicle-based emissions testing at least once every three months to get a more accurate picture of the emissions that occur from specific vehicles in the city. Singh et al. (2001) stated that 3.5 million automobiles in Delhi provide roughly 70% of the overall air pollution load.

Several studies have been conducted based on healthcare costs incurred as a result of air pollution-related disorders in various areas (Ghosh, 2019; Maji, et al., 2017; Saxena, 2012; Srivastava and Kumar, 2002; McCubbin and Delucchi, 1999; Lvovsky, 1998). Ghosh (2019) reported that India has one of the highest levels of air pollution in the world. Nearly half of India's premature mortality are due to $PM_{2.5}$ in the Indo-Gangetic Basin, the country's most densely populated region. Maji et al. (2017) analyzed the monetary cost burden associated with health impacts caused by air pollution. The number of instances grew 13.43% to about 27.52% between 2002 and 2014 and the related costs had

increased at a quick rate from US$ 67.99 million to US$ 254.52 million. On comparing the economic cost of air pollution of various diseases, Saxena (2012) calculated the economic cost of the health effects from 2006 to 2010 and estimated it to be INR 49.45 million; respiratory and bronchitis(RB) accounted for a higher economic cost of INR 37,77,345, accounting for 76.38 % of the total cost.

The lost salary approach was used to attempt an economic assessment of morbidity and death, which revealed that the avoidance cost is 29 % of the total health damage cost (Srivastava and Kumar, 2002). Particulate matter is the most harmful contaminant, according to McCubbin and Delucchi (1999), while ozone and other pollutants have minor effects. Diesel vehicles inflict more harm per mile than gasoline vehicles due to higher particle emissions; therefore it is advised that particulate regulation be prioritised.

In comparison to other countries, India has a disproportionately high health burden from urban air pollution. Lvovsky (1998) reported that India suffers from a disproportionally heavy health burden of urban air pollution by international comparison with the meta-analysis and monitors measuring either PM_{10} or $PM_{2.5}$, annual productivity losses of US $ 800 million were discovered in 12 of India's main cities and health damages increased from 3% for the sample average to 95 for India.

Using an identified emission model to predict realistic emissions, Thakur and pal (2018) discovered that total yearly emissions from 1, 20,000 auto rickshaws in Bangaluru amount to 0.45 million tonnes, 1445 tonnes, and 164 tonnes of CO_2, NOx, and PM_{10}, respectively. They recommended converting to LPG (Liquefied Petroleum Gas) since auto rickshaws in Bengaluru emit approximately 1200 tonnes of carbon dioxide, 4 tonnes of NOx, and 0.5 tonnes of PM_{10}.Kumar and Tripathy (2015)reported that the use of LPG reduces toxic emissions by 90% and carbon dioxide emissions by 22%-24% when compared to gasoline, and the use of CNG (Compressed Natural Gas) reduces greenhouse gas emissions by 12% when compared to diesel engines, and the impact of pollutants on human health ranges from minor illnesses to life-threatening diseases. Gouret al. (2015) investigated the role of electric vehicles in lowering pollution in several areas. He offered viable options for pollution control, which can also be accomplished by reducing the volume of traffic on highways.

Various studies have been focused on the risk assessment, perception of social factors, and awareness among people about air pollution (Fiksel et al., 2021; Kumar et al., 2020; Mishra and Kulshrestha,

2020; Pant et al., 2015). Fiksel et al. (2021) reported that the development of circular economy solutions that establish novel paths for repurposing rejected materials in order to eliminate waste is a priority. Nature-based methods for air pollution reduction, according to Kumar et al. (2020), can be done by educating people ecologically concerned through value-based education.

Mishra and Kulshrestha (2020) discovered significantly higher concentrations of cations and anions at both urban and rural sites, owing to higher humidity during the winter and resulting aqueous-phase chemistry at both sites of the Indo-Gangetic Basin and estimated fossil fuel combustion, solid waste and biofuel burning as the major anthropogenic contributors at the urban site, whereas biomass burning, brick kiln combustion, and agricultural activity were the major anthropogenic contributors at the rural site. Pant et al. (2015) discovered that pollution from primary and secondary sources in Delhi is much higher in the winter than in the summer and that pollutant concentrations are influenced by both meteorological and source strength.

Justification for the Research

Air pollution is not just a major worldwide issue; it also poses a serious threat of the survival of human being at the regional and local levels. Particulate matter concentrations are substantially greater than WHO guidelines in numerous parts of the world. According to the State of Global Air 2020 (SOGA 2020) study, air pollution ranks fourth among 87 health risk factors based on the total number of fatalities caused in 2019, ahead of high systolic blood pressure, cigarettes, and dietary hazards. These effects appear to be worsening in the near future, necessitating a greater understanding of air pollution issues in order to address the threat of air pollution and accomplish the aim of sustainable development.

It is one of the world's most polluted places, and it is home to 40% of India's population. In India, the urban population is the primary source of air pollution, and individuals are facing extinction threats. Air pollution has been measured all over the world, but the health effects of air pollution have not been researched in a vast part of the globe. There has been relatively little economic research of the health effects of particulate matter, and no such systematic study has been reported for the Indo-Gangetic region. It is critical and a difficult task as well to reduce emissions and accomplish the Sustainable Development Goals. It necessitates formulation and implementation of a comprehensive

strategy. Although different policies or control measures are required for different regions to reduce economic loss and save human welfare, and circular economy approach can be used as a tool in a few parts of the world to reduce air pollution from specific sources; none has used in India, particularly in the Indo-Gangetic basin.

Objectives

Air pollution has spread over the world, wreaking havoc on human health, vegetation, materials, and the ecology. Particulate matter has put human health at risk by causing respiratory and pulmonary disorders, as well as early death. These effects have a number of economic ramifications, and are expected to worsen as particulate matter concentrations rise. Hence, air pollution needs to be controlled on urgent basis to improve human economic conditions and life expectancy. As sources of air pollution and the economic impacts of air pollution are so disparately spread across the country, strategies must be customised to individual local situations.

India's air quality is terrible, especially in the cities in the Indo-Gangetic basin. Patiala (Punjab); Faridabad (Haryana); Delhi; Kanpur and Agra (Uttar Pradesh); Muzaffarpur (Bihar); and Kolkata (West Bengal) are among the most polluted cities in the Indo-Gangetic basin; as a result general public suffers a lot. Since, proper efforts in the direction of pollution reduction and research into the economic burdens associated with air pollution-related health effects are lacking, proposed research aims to focus on following objectives:

(i) To study the concentration of Particulate matter (PM) of selected cities (Patiala, Faridabad, Delhi, Kanpur, Agra, Muzaffarpur, and Kolkata) over the Indo-Gangetic basin (IGB) region of India.

(ii) To study the seasonal variation in concentration of PM over the selected cities.

(iii) To assess the health risk (including mortality and morbidity) of air pollution in selected cities.

(iv) To evaluate the economic loss (by taking impacts on premature deaths and illness cost) due to air pollution in selected cities and

(v) To develop a circular economy model to combat the menace of air pollution.

3. Methodology

3.1 Site Characteristics

The proposed investigation will take place in seven key cities (Patiala, Faridabad, Delhi, Kanpur, Agra, Muzaffarpur, and Kolkata) of IGB region of India. Faridabad, Delhi, Agra, Kanpur, and Muzaffarpur are among 22 of the world's 30 most polluted cities in 2020. There are also many factors that lead to air pollution, which are the reason for many health issues and smog in Patiala and Kolkata. The IGB (North Indian Basin) is a delta formed by the Brahmaputra River valley and the Ganga River, which connects to the Indus River basin. The most heavily inhabited and polluted areas are found in this region. Patiala is a very polluted and congested city in south-eastern region of Punjab. In the Indian state of Haryana, Faridabad is the most populous city. Delhi, India's capital is recognised as the world's most polluted capital city. Agra is a historically significant and well-known tourist destination, but it is also one of the most polluted cities in the world. Kanpur, one of the most important commercial and military centres of India, but highly polluted. Muzaffarpur is a city in Bihar that is on the Indo-Gangetic basin. Kolkata is also one of India's most densely populated and polluted cities and is capital of the Indian state of West Bengal.

3.2 Sampling and Analysis

The monitor air quality of selected cities, data on mass concentrations of PM_{10} and $PM_{2.5}$ will be obtained from the CPCB (Central Pollution Control Board of India). The CPCB measures particulate matter concentrations in the atmosphere in micrograms per cubic metre. For all the selected stations, all accessible data for the research period (from 2021 to 2023) will be downloaded. For the investigation, the daily mean concentration will be employed. In Agra, Politech/Envirotech dust samplers will be used to collect $PM_{2.5}$ and PM_{10} on the top of the Technical College building of Dayalbagh Educational Institute (Deemed University), Dayalbagh. As a collecting surface, a pre-weighed glass fibre filter will be employed. Gravimetric analysis will be used to determine the mass concentration.

Health risk analysis of air pollution

- **Exceedance Factor:** The Exceedance Factor (EF) is a ratio of a pollutant's annual mean concentration to that of a standard (NAAQS, 2014). The acceptance of daily limit concentration and

mean mass concentration are in use to describe particle matter concentration levels in ambient air. It's a valuable tool for analysing how air quality is deteriorating as pollution levels rise. EF for selected cities will be determined using the following formula:

$$\text{Exceedance Factor (EF)} = \frac{\text{Observed concentration of criteria pollutant}}{\text{Annual standard for the respective pollutant and area class}}$$

The four categories of EF which describe health risk due to air quality are as follows: when EF is > 1.5 = Critical health risk (C); when EF is between 1.0 to 1.5 = High health risk (H); when EF is between 0.5 to 1.0 = Moderate health risk (M) and when EF is < 0.5 = Low health risk (L)

- **Exposure contributions and health impact calculations:** Using the formulae below, the population-weighted mean concentration will be calculated to evaluate the risk of pollutants on exposed populations in that specific location:

$$\sum_{i=1}^{n} \frac{Pi \times Ci}{Ptot}$$

Where i designates each computational cell in the domain, Pi is the population at a given cell location, Ci is the particulate concentration in the same cell location, and Ptot is the total population in the domain of interest (i.e., air basin-wide total population).The overall population for the computational cell will be taken for all seven specified places in the current study, and the population at each cell location will be considered for a specific region.

- **Health hazard**: The AirQ+ v.1.2 model will be used to estimate the health risk assessment owing to pollution (World Health Organization, 2016). The AirQ+v.1.2 software incorporates the risk of death from $PM_{2.5}$ and PM_{10}, as well as the effects of long and short-term exposure on human health over time. The AirQ+ v.1.2 programme incorporates WHO recommended input of relative risk (RR) values (per 10 g m^{-3}) and occurrences for various air contaminants and illness categories (e.g., cardiovascular, respiratory, hospital admissions, respiratory disease, etc.)(WHO, 2006; WHO, 2014). The population attributable fraction (PAF), which is defined as the fraction of health outcomes in the public exposed to a certain air pollution, is used to estimate health risk (Maji et al., 2017).

The AirQ+ v.2.0 model (World Health Organization, 2016) is used to assess mortality and morbidity as a result of air pollution levels. It combines risk of death, the attributable factor of particulate matter,

and the effects of long-term exposure on human health. The incidence rate in the exposed population (per 100,000 populations per year) is compared to the incidence rate in the counterfactual population with known relative risks (RR) of exposure in AirQ+ v.2.0.

$$\mathrm{RR} = \frac{\text{Probability of exposed to air pollution}}{\text{Probability of not exposed to air pollution}}$$

In the calculation of RR in ambient air pollution, the whole population will be assumed to be exposed. Population attributable fraction (PAF) estimates the proportion of cases that are prevented if the exposure would be zero. In case the whole population is exposed.

$$\mathrm{PAF} = \frac{\mathrm{RR} - 1}{\mathrm{RR}}$$

If the level of exposure will be reduced in a population to a (counterfactual) level where RR is equal to one, PAF would be zero. If only a fraction p of a population is exposed, the formula is generalized to:

$$\mathrm{PAF} = \frac{\mathrm{p}\ (\mathrm{RR} - 1)}{\mathrm{p}\ (\mathrm{RR} - 1)}, 0 < p \leq 1$$

Hospital Admission and pollution concentration

To examine effect of concentration of particulate matter on human health, human hospital admissions data will be acquired from famous hospitals' outpatient departments in chosen cities and correlation will be established between concentration of particulate matter and hospital admissions.

- **Economic evaluation:**

A standard method for estimating the monetary cost of a positive welfare effect, e.g., a reduction in mortality risk, is to create a hypothetical market for the mortality risk considered and derive based on the VSL (value of statistical life) (Maji, et al., 2018; and Lelieveld, 2018; Xie, 2011). The monetary burden due to the health risk of air pollution will be calculated using VSLmethod. The market value for human lives is unreachable; the monetary burden due to the health risk of air pollution will be calculated using the method of VSL

$$\mathrm{VSL} = \sum_{\mathrm{t}=0}^{\mathrm{x}} \mathrm{w}/(1 + \mathrm{d})\mathrm{t}$$

Where, w = average annual income, t = life expectancy – the average age of the population, d = the discount rate (5% according to USA guidelines for global health; Haacker et al., 2019) and x = difference between life expectancy and the average age of the population.

- **Economic burden**

The total economic health burden in a province i can be evaluated by multiplying the number of disease-specific health impacts (HI_i) attributableto particulate matter in province i with the corresponding $HC_{i,y}$ valueusing the following equation:

$$\text{Economic Burden} = HI_i \times HC_{i,y}$$

Where,$HC_{i,y}$is the adjusted health cost for province i in y year; which can be calculated using the following formula (Maji, et al., 2018):

$$HC_{i,y} = HC_{C/B,k} \times \left(\frac{G_{i,k}}{G_{C/B,k}}\right)^{\beta} \times (1 + \%\Delta P_i + \%\Delta G_i)^{\beta}$$

$HC_{C/B,k}$is the base value of health cost for India or New Delhi in the year k; $G_{i,k}$ is the GDP per capita in purchasing power parity (PPP) terms in province i in the year k; β is the income elasticity of health cost equals to0.8 as recommended by OECD (OECD, 2016); $\%\Delta P_i$ and $\%\Delta G_i$ are the percentage increase/decrease in consumer price index (CPI) and GDP per capita in the province i during the year k to the study year.

Circular economy indicators identification

A survey based on questionnaires will be used to identify circular economy indicators to combat the threat of air pollution. The core data for this study will be collected through an evenly distributed survey of minimum 1000 respondents. A questionnaire will be devised to identify the circular's indications for each region separately. Information will be collected from various departments, colleges, and schools, as well as common people in selected cities, using questionnaires that will be distributed to the local population. The response could be a true reflection of the general public's feelings about global issues like air pollution and how to address them through a circular economy.

Statistical Analysis

The datasets will be subjected to statistical analysis using SPSS. Mean, standard deviation, range, correlation, regression, and ANOVA will be performed in the datasets. The statistical significance of

the collected survey data will be determined using an appropriate non-parametric method. The t-test will be used to determine the association between two categories of variables, such as gender, location, and age. The significant level $p<0.05$ will be used.

Expected outcome

The proposed study will be the first of its kind, in which analysing the state of air quality in major cities throughout the Indo-Gangetic basin, assessing health risks and the economic burden associated with health impacts, and proposing a circular economy based model for a number of selected cities to combat the threat of air pollution will be performed. This research will establish a new paradigm in the field of reducing emissions from various sources of air pollution. Estimating the economic burden of health risks will aid in nation-building and the protection of human lives from air pollution. The data obtained will be useful for academicians, non-government organizations (NGOs), Government authorities, the stakeholders and policy makers.

References

- Adeyanju, A. A., and Manohar, K., 2017. Effects of vehicular emission on environmental pollution in Lagos. Sci-Afric Journal of Scientific Issues, Research, and Essays5 (4), 034-051.
- Adhikary, S. D., Dhar, S., Dutta, S., Mondal, S., Ghosh, S., Mallick, S., and Das, P., 2020. Continuous onboard vehicle emission monitoring through IoT. International Journal for Research in Applied Science & Engineering Technology 8(V), 2321-9653.
- Ahuja, J., Dawson, L., and Lee, R., 2020. A circular economy for electric vehicle batteries; driving the change. Journal of Property Planning and Environment Law 12(3), 235-250.
- Balasundaram, A., Udayakumar, A., Gopalan, B., Bhaskaran, K., and Muthalip, B. A., 2017. IoT (Internet of Things) based vehicle emission monitoring system. IJIRST (International Journal of Innovative Science and Research Technology) National Conference on Networks, Intelligence and Computing Systems.
- Brauer, M., Hoek, G., Smit, H. A., de Jongste, J. C., Gerritsen, J., Postma, D. S., Kerkhof, M., and Brunekreef, B., 2007. Air pollution and development of asthma, allergy, and infections in a birth cohort. The European Respiratory Journal 29, 879-888.

- Donald, A. R. G., Lin, B. Chi-ang, and Chen, Y., 2015. A circular economy model of economic growth. Environmental Modelling and Software 73, 60-63.
- Ferrante, L. and Germani, A. R., 2020. Does a circular economy play a key role in economic growth? Economics Bulletin 40 (3) 1855-1862.
- Fiksel J., Sanjay P. and Raman K., 2021. Steps toward a resilient circular economy in India. Clean Technologies and Environmental Policy 23, 203–218.
- Ghorani-Azam, A., Riahi-Zanjani, B., and Balali-Mood, M., 2016. Effects of air pollution on human health and practical measures for prevention in Iran. Journal of Research in Medical Sciences, 1735-1995.
- Ghosh, S., 2019. Emissions in Indo Gangetic Basin are linked to nearly half of untimely deaths due to outdoor air pollution. Environment and Health, Hewing the Regulatory Tree, Colorado State University.
- Giannadaki, D., and Lelieveld J., 2018. Estimating health and economic benefits of reductions in air pollution from agriculture. Science of the total Environment 622–623, 1 May 2018, 1304-1316
- Gour, A., Singh, S. K., Tyagi, S. K., and Mandal, A., 2015. Variation in parameters of ambient air quality in National Capital Territory (NCT) of Delhi (India).Atmospheric and Climate Sciences (1), 13-22.
- Haacker, M., Hallett, T.B., and Atun, R., 2019. On discount rates for economic evaluations in global health. Health Policy and Planning 35, 2020, 107–114.
- Howel, D., Moffatt, S., Bush, J., Dunn, C. E., and Prince, H., 2003. Public views on the links between air pollution and health in northeast England. Environmental Research 91(3), 163-171.
- Kumar, A., and Tripathy, S., 2015. Study of vehicular pollution and its mitigation measures.3rd KIIT International Symposium on Advances in Automotive Technology.

- Kumar, R., Gupta, P., and Jangid, A., 2020. An empirical study towards air pollution control in Agra, India: a case study. SN Applied Sciences 2:2090. doi.org/10.1007/s42452-020-03826-4.
- Liu, H., Kobernus, M., and Liu, H., 2017. A public perception survey study on air quality issues in Wuhan, China. Journal of Environmental Protection (8), 1194-1218.
- Liu, Z., Adams, M., Cote, R. P., Chen, Q., Wu, R., Wen, Z., Liu, W., and Dong, L., 2018. How does circular economy respond to greenhouse gas emissions reduction: An analysis of Chinese plastic recycling industries? Renewable and Sustainable Energy Reviews 91, 1162-1169.
- Lvovsky, K., 1998. Economic costs of air pollution with special reference to India. Prepared for the National Conference on Health and Environment Delhi, India, South Asia Environment Unit World Bank.
- Mahadevappa, H., 2012. A study on air pollution by automobiles in Bangalore city. Management Research and practice 4(3), 25-36.
- Maji, K. J., Dikshit, A. K., and Deshpande, A., 2017. Assessment of city level human health impact and corresponding monetary cost burden due to air pollution in India taking Agra as a model city. Aerosol and Air Quality Research 17, 831–842.
- Maji, K. J., Wei-Feng Ye, W. F., Arora, M., Nagendra, S. M. S., 2018. $PM_{2.5}$-related health and economic loss assessment for 338 Chinese cities. Environment International 121 (2018) 392–403.
- McCubbin, D.R., and Delucchi, M. A., 1999. The health costs of motor-vehicle-related air pollution. Journal of Transport Economics and Policy 33(3), 253-286.
- Mishra, M., and Kulshrestha, U.C., 2020. Extreme air pollution events spiking ionic levels at urban and rural sites of Indo-Gangetic Basin. Aerosol and Air Quality Research 20, 1266–1281.

- Pant, P., Shukla, A., Kohl, S., Chow, J. C., Watson, J. G., and Harrison, R.M., 2015. Characterization of ambient $PM_{2.5}$ at a pollution hotspot in Delhi, India, and inference of sources. University of Birmingham research at Birmingham 109(25) 178-189.
- Raut, A. K., 2003. Role of electric vehicles in reducing urban air pollution: A Case of Kathmandu. Better Air Quality, 2003 Workshop 17-19 December 2003, Manila, Philippines.
- Saxena, N. K., 2012. (PhD Thesis) Cost analysis of air pollutants on human health in Agra. https://shodhganga.inflibnet.ac.in/handle/10603/209568
- Sharma, R., 2018. Health and economic growth: Evidence from dynamic panel data of 143 years. PLoS ONE 13(10), e0204940.
- Shrivastava, R. K., Saxena, N., and Gautam, G., 2013. Air pollution due to road transportation in India: a review on assessment and reduction strategies. Journal of Environmental Research and Development 8(1), NS2.
- Singh, A., Sharma, N., Sharma, K., and Bhan, C., 2001. Emission characteristics of in-use CNG vehicles in Delhi. Central Road Research Institute, New Delhi-110 020Tel: 91-11-6846976; e-mail: anil@cscrri.ren.nic.in.
- Sommer, H., Seethaler, R., Chanel, O., Herry, M., Masson, S., and Vergnaud, J. C., 1999. Economic evaluation of health impacts due to road traffic-related air pollution-an impact assessment project of Austria, France, and Switzerland. Federal Department of Environment, Transport, Energy and Communications Bureau for Transport Studies, 451-479.
- Srivastava, A., and Kumar, R., 2002. Economic evaluation of the health impacts of air pollution in Mumbai. Environmental Monitoring and Assessment 75(2), 135-143.
- Su, B., Heshmati A., Geng Y., and Yu X., 2013. A review of the circular economy in China: moving from rhetoric to implementation. Journal of Cleaner Production 42, 215-227.
- Tanimowo, N. B., 2016. Survey of automobile smoke emissions for environmental management in Nigerian cities. International Journal of Scientific & Engineering Research 7(1), 2229-5518.

- Taylor, K, 2021. Circular Economy, Euractiv.https://www.euractiv.com/section/circular-economy/news/circular-economy-could-reduce-greenhouse-gas-emissions-by-39/
- Thakur, P., and Pal, S., 2018. Estimating vehicular emissions from auto-rickshaws plying in Bengaluru city. International Journal of Scientific and Engineering Research 9 (5), 2229-5518.
- Xie, Y., 2011. Values and limitations of statistical models. Research in Social Stratification and Mobility 29(3):343-349, PubMed. doi:10.1016/j.rssm.2011.04.001
- Yadav, S. K., and Sahay, M., 2017.A study on automobile industry growth in India and its impact on air pollution. Journal of Advanced Research in Dynamical and Control System 17, 1901-1909.
- **Reports**
- Accenture and the world economic forum, 2021.https://newsroom.accenture.com/news/the-circular-economy-can-help-reduce-vehicle- lifetime- emissions-by-up-to-75-percent-by-2030-according-to-accenture-and-the-world-economic-forum.htm
- Circularity Gap Reporting Initiative-CGR 2021. https://www.circularity-gap.world.
- Ellen Macarthur Foundation, 2016. Circular economy in India: Rethinking growth for long-term prosperity. https://ellenmacarthurfoundation.org/circular-economy-in-india
- Ellen Macarthur Foundation, 2021.https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview
- FICCI Circular Economy Symposium, 2018. FICCI-Accenture - Circular Economy Report – OptVer, SCRIBD.
- Health and economic analysis of death due to air pollution in India: the Global Burden Disease Study 2019. OECD Publishing, Paris. OECD, 2021.
- Indian Air Quality Index (AQI) and IQAir, 2020.https://www.iqair.com/india
- International EMF Project- Progress reports-June 2015-2016. https://www.who.int/publications/m/item/international-emf-project-progress-report-2015-2016
- National Ambient Air Quality Standards (NAAQS), 2014. Air and Radiation, US EPA. https://www.epa.gov/sites/default/files/2015-02/documents/criteria.pdf

- State of Global Air (SOGA, 2020) report. https://www.stateofglobalair.org
- Support sustainable development and climate action- the United Nations. https://www.un.org/en/our-work/support-sustainable-development-and-climate-action.
- The 2030 Agenda for sustainable development. UNSSC Knowledge Centre for Sustainable Development Martin-Luther-King-Strasse 8, 53175 Bonn, Germany +49 (0) 228 815 2657 sustainable-development@unssc.org www.unssc.org
- The Circularity Gap Report, 2018. Our world is only 9 percent circular.https://www.circle-economy.com/news/the-cicularity-gap-report-our-world-is-only-9-circular.
- The Circularity Gap Report, 2020.https://www.circle-economy.com/news/our-world-is-now-only-8-6-circular
- The economic consequences of outdoor air pollution. OECD Publishing, Paris. OECD, 2016.
- The Green Wall of India, proposed by environmental activist Vijaypal Baghel at the September Conference of Parties (COP14) by the United Nations Convention to Combat Desertification (UNCCD) in New. Indian Express, 24 December 2019.
- World air quality report, 2020.https://www.iqair.com/world-most-polluted-cities/world-air-quality-report-2020-en.pdf
- World Health Organization (WHO), 2003, 2006, 2014, 2016, and 2018. World Health Statistics. https://www.who.int/data/gho/publications/world-health-statistics.